

An Introduction to *GenomeInfoDb*

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Contents

1	Introduction	2
2	Functionality for all existing organisms.	2
2.1	genomeStyles	2
2.2	extractSeqlevels	3
2.3	extractSeqlevelsByGroup	3
2.4	seqlevelsStyle	3
2.5	seqlevelsInGroup	4
2.6	orderSeqlevels	4
2.7	rankSeqlevels	5
2.8	mapSeqlevels	5
2.9	renameSeqlevels	6
2.10	dropSeqlevels	6
2.11	keepSeqlevels	7
2.12	keepStandardChromosomes	7
3	Classes inside GenomeInfoDb package	8
3.1	Genome-Description class	8
3.2	Seqinfo class	9
4	Examples	12
4.1	converting seqlevel styles (eg:UCSC to NCBI)	12
4.2	converting styles and removing unwanted seqlevels	13
5	Session Information	14

1 Introduction

The *GenomeInfoDb* provides an interface to access seqlevelsStyles (such as UCSC, NCBI, Ensembl) and their supported mappings for organisms. For instance, for Homo sapiens, seqlevelsStyle "UCSC" maps to "chr1", "chr2", ..., "chrX", "chrY". The section below introduces these functions with examples.

2 Functionality for all existing organisms

2.1 genomeStyles

The `genomeStyles` lists out for each organism, the seqlevelsStyles and their mappings.

```
seqmap <- genomeStyles()
head(seqmap,n=2)

## $Arabidopsis_thaliana
##   circular auto sex NCBI TAIR9 Ensembl
## 1  FALSE  TRUE FALSE   1 Chr1      1
## 2  FALSE  TRUE FALSE   2 Chr2      2
## 3  FALSE  TRUE FALSE   3 Chr3      3
## 4  FALSE  TRUE FALSE   4 Chr4      4
## 5  FALSE  TRUE FALSE   5 Chr5      5
## 6   TRUE FALSE FALSE  MT  ChrM     Mt
## 7   TRUE FALSE  TRUE Pltd ChrC     Pt
##
## $Caenorhabditis_elegans
##   circular auto sex NCBI UCSC Ensembl
## 1  FALSE  TRUE FALSE   I chrI      I
## 2  FALSE  TRUE FALSE  II chrII     II
## 3  FALSE  TRUE FALSE III chrIII    III
## 4  FALSE  TRUE FALSE  IV chrIV     IV
## 5  FALSE  TRUE FALSE   V chrV      V
## 6  FALSE FALSE  TRUE   X chrX      X
## 7   TRUE  TRUE FALSE  MT chrM     MtDNA
```

Organism's supported by GenomeInfoDb can be found by :

```
names(genomeStyles())

## [1] "Arabidopsis_thaliana"      "Caenorhabditis_elegans"
## [3] "Canis_familiaris"         "Cyanidioschyzon_merolae"
## [5] "Drosophila_melanogaster"   "Homo_sapiens"
## [7] "Mus_musculus"             "Oryza_sativa"
## [9] "Populus_trichocarpa"      "Rattus_norvegicus"
## [11] "Saccharomyces_cerevisiae" "Zea_mays"
```

If one knows the organism one is interested in, then we can directly access the information for the given organism along. Each function accepts an argument called species which as "genus species", the default is "Homo sapiens". In the following example we list out only the first five entries returned by the code snippet.

```
head(genomeStyles("Homo_sapiens"),5)

##   circular auto   sex NCBI UCSC dbSNP Ensembl
## 1    FALSE TRUE FALSE   1 chr1  ch1      1
## 2    FALSE TRUE FALSE   2 chr2  ch2      2
## 3    FALSE TRUE FALSE   3 chr3  ch3      3
## 4    FALSE TRUE FALSE   4 chr4  ch4      4
## 5    FALSE TRUE FALSE   5 chr5  ch5      5
```

We can also check if a given style is supported by GenomeInfoDb for a given species. For example, if we want to know if "UCSC" mapping is supported for "Homo sapiens" we can ask :

```
"UCSC" %in% names(genomeStyles("Homo_sapiens"))

## [1] TRUE
```

2.2 extractSeqlevels

We can also extract the desired seqlevelsStyle from a given organism using the `extractSeqlevels`

```
extractSeqlevels(species="Arabidopsis_thaliana", style="NCBI")

## [1] "1" "2" "3" "4" "5" "MT" "Pltd"
```

2.3 extractSeqlevelsByGroup

We can also extract the desired seqlevelsStyle from a given organism based on a group (Group - 'auto' denotes autosomes, 'circular' denotes circular chromosomes and 'sex' denotes sex chromosomes; the default is all chromosomes are returned).

```
extractSeqlevelsByGroup(species="Arabidopsis_thaliana", style="NCBI",
                        group="auto")

## [1] "1" "2" "3" "4" "5"
```

2.4 seqlevelsStyle

We can find the seqname Style for a given character vector by using the `seqlevelsStyle`

```
seqlevelsStyle(paste0("chr",c(1:30)))

## [1] "UCSC"

seqlevelsStyle(c("2L","2R","X","Xhet"))
```

```
## [1] "NCBI"
```

2.5 seqlevelsInGroup

We can also subset a given character vector containing seqnames using the `seqlevelsInGroup`. We currently support 3 groups: 'auto' for autosomes, 'sex' for allosomes/sex chromosomes and circular for 'circular' chromosomes. The user can also provide the style and species they are working with. In the following examples, we extract the sex, auto and circular chromosomes for Homo sapiens :

```
newchr <- paste0("chr",c(1:22,"X","Y","M","1_gl000192_random","4_ctg9_hap1"))
seqlevelsInGroup(newchr, group="sex")

## [1] "chrX" "chrY"

seqlevelsInGroup(newchr, group="auto")

## [1] "chr1" "chr2" "chr3" "chr4" "chr5" "chr6" "chr7" "chr8" "chr9"
## [10] "chr10" "chr11" "chr12" "chr13" "chr14" "chr15" "chr16" "chr17" "chr18"
## [19] "chr19" "chr20" "chr21" "chr22"

seqlevelsInGroup(newchr, group="circular")

## [1] "chrM"

seqlevelsInGroup(newchr, group="sex","Homo_sapiens","UCSC")

## [1] "chrX" "chrY"
```

if we have a vector containing seqnames and we want to verify the species and style for them , we can use:

```
seqnames <- c("chr1", "chr9", "chr2", "chr3", "chr10")
all(seqnames %in% extractSeqlevels("Homo_sapiens", "UCSC"))

## [1] TRUE
```

2.6 orderSeqlevels

The `orderSeqlevels` can return the order of a given character vector which contains seqnames. In the following example, we show how you can find the order for a given seqnames character vector.

```
seqnames <- c("chr1","chr9", "chr2", "chr3", "chr10")
orderSeqlevels(seqnames)

## [1] 1 3 4 2 5

seqnames[orderSeqlevels(seqnames)]

## [1] "chr1" "chr2" "chr3" "chr9" "chr10"
```

2.7 rankSeqlevels

The `rankSeqlevels` can return the rank of a given character vector which contains seqnames. In the following example, we show how you can find the rank for a given seqnames character vector.

```
seqnames <- c("chr1", "chr9", "chr2", "chr3", "chr10")
rankSeqlevels(seqnames)

## [1] 1 4 2 3 5
```

2.8 mapSeqlevels

Returns a matrix with 1 column per supplied sequence name and 1 row per sequence renaming map compatible with the specified style. If `best.only` is `TRUE` (the default), only the "best" renaming maps (i.e. the rows with less NAs) are returned.

```
mapSeqlevels(c("chrII", "chrIII", "chrM"), "NCBI")

## chrII chrIII chrM
##  "II"  "III"  "MT"
```

We also have several seqlevel utility functions. Let us construct a basic `GRanges` and show how these functions can be used. .

```
gr <- GRanges(paste0("ch", 1:35), IRanges(1:35, width=5))
gr

## GRanges object with 35 ranges and 0 metadata columns:
##      seqnames      ranges strand
##      <Rle> <IRanges> <Rle>
##   [1]    ch1        1-5      *
##   [2]    ch2        2-6      *
##   [3]    ch3        3-7      *
##   [4]    ch4        4-8      *
##   [5]    ch5        5-9      *
##   ...      ...          ...   ...
##  [31]   ch31       31-35      *
##  [32]   ch32       32-36      *
##  [33]   ch33       33-37      *
##  [34]   ch34       34-38      *
##  [35]   ch35       35-39      *
##  -----
##  seqinfo: 35 sequences from an unspecified genome; no seqlengths
```

As you can see, we have "ch" instead of "chr" for chromosome names. We can use `renameSeqlevels` to change the "ch" to "chr"

2.9 renameSeqlevels

As the first argument - it takes the object whose seqlevels we need to change, and as the second argument it takes a named vector which has the changes.

```
newnames <- paste0("chr",1:35)
names(newnames) <- paste0("ch",1:35)
head(newnames)

##   ch1   ch2   ch3   ch4   ch5   ch6
## "chr1" "chr2" "chr3" "chr4" "chr5" "chr6"

gr <- renameSeqlevels(gr,newnames)
gr

## GRanges object with 35 ranges and 0 metadata columns:
##      seqnames      ranges strand
##      <Rle> <IRanges>  <Rle>
##   [1]   chr1         1-5      *
##   [2]   chr2         2-6      *
##   [3]   chr3         3-7      *
##   [4]   chr4         4-8      *
##   [5]   chr5         5-9      *
##   ...    ...         ...     ...
##  [31]  chr31        31-35      *
##  [32]  chr32        32-36      *
##  [33]  chr33        33-37      *
##  [34]  chr34        34-38      *
##  [35]  chr35        35-39      *
## -----
## seqinfo: 35 sequences from an unspecified genome; no seqlengths
```

Humans have just 22 primary chromosomes - but here we have some extra seqlevels which we want to remove - there are several ways we can achieve this:

2.10 dropSeqlevels

Here the second argument is the seqlevels that you want to drop. Because these seqlevels are in use (i.e. have ranges on them), the ranges on these sequences need to be removed before the seqlevels can be dropped. We call this *pruning*. The `pruning.mode` argument controls how to prune `gr`. Unlike for list-like objects (e.g. `GRangesList`) for which pruning can be done in various ways, pruning a `GRanges` object is straightforward and achieved by specifying `pruning.mode="coarse"`.

```
dropSeqlevels(gr, paste0("chr",23:35), pruning.mode="coarse")

## GRanges object with 22 ranges and 0 metadata columns:
##      seqnames      ranges strand
##      <Rle> <IRanges>  <Rle>
##   [1]   chr1         1-5      *
##   [2]   chr2         2-6      *
##   [3]   chr3         3-7      *
```

```
## [4] chr4 4-8 *
```

	seqnames	ranges	strand
## [5]	chr5	5-9	*
##
## [18]	chr18	18-22	*
## [19]	chr19	19-23	*
## [20]	chr20	20-24	*
## [21]	chr21	21-25	*
## [22]	chr22	22-26	*

```
## -----
## seqinfo: 22 sequences from an unspecified genome; no seqlengths
```

2.11 keepSeqlevels

Here the second argument is the seqlevels that you want to keep.

```
keepSeqlevels(gr, paste0("chr",1:22), pruning.mode="coarse")
```

```
## GRanges object with 22 ranges and 0 metadata columns:
##      seqnames      ranges strand
##      <Rle> <IRanges> <Rle>
## [1] chr1      1-5      *
```

	seqnames	ranges	strand
## [2]	chr2	2-6	*
## [3]	chr3	3-7	*
## [4]	chr4	4-8	*
## [5]	chr5	5-9	*
##
## [18]	chr18	18-22	*
## [19]	chr19	19-23	*
## [20]	chr20	20-24	*
## [21]	chr21	21-25	*
## [22]	chr22	22-26	*

```
## -----
## seqinfo: 22 sequences from an unspecified genome; no seqlengths
```

2.12 keepStandardChromosomes

This function internally uses the pre-defined tables inside GenomeInfoDb to find the correct seqlevels according to the sequence style of the object.

```
keepStandardChromosomes(gr, pruning.mode="coarse")
```

```
## GRanges object with 35 ranges and 0 metadata columns:
##      seqnames      ranges strand
##      <Rle> <IRanges> <Rle>
## [1] chr1      1-5      *
```

	seqnames	ranges	strand
## [2]	chr2	2-6	*
## [3]	chr3	3-7	*
## [4]	chr4	4-8	*
## [5]	chr5	5-9	*

```
##      ...      ...      ...      ...
## [31] chr31    31-35      *
## [32] chr32    32-36      *
## [33] chr33    33-37      *
## [34] chr34    34-38      *
## [35] chr35    35-39      *
## -----
## seqinfo: 35 sequences from an unspecified genome; no seqlengths
```

One can also specify the optional species argument to be more precise.

```
plantgr <- GRanges(c(1:5,"MT","Pltd"), IRanges(1:7,width=5))
keepStandardChromosomes(plantgr, species="Arabidopsis thaliana",
                        pruning.mode="coarse")

## GRanges object with 7 ranges and 0 metadata columns:
##      seqnames      ranges strand
##      <Rle> <IRanges> <Rle>
## [1]      1      1-5      *
## [2]      2      2-6      *
## [3]      3      3-7      *
## [4]      4      4-8      *
## [5]      5      5-9      *
## [6]      MT      6-10     *
## [7]     Pltd      7-11     *
## -----
## seqinfo: 7 sequences from an unspecified genome; no seqlengths
```

3 Classes inside GenomeInfoDb package

3.1 Genome-Description class

We also provide a Genome Description class which can be used in the following way:

```
library(BSgenome.Celegans.UCSC.ce2)
class(Celegans)

## [1] "BSgenome"
## attr(,"package")
## [1] "BSgenome"

is(Celegans, "GenomeDescription")

## [1] TRUE

provider(Celegans)

## [1] "UCSC"

seqinfo(Celegans)

## Seqinfo object with 7 sequences (1 circular) from ce2 genome:
```



```
## seqnames seqlengths isCircular genome
## chrI      15080483      FALSE    ce2
## chrII     15279308      FALSE    ce2
## chrIII    13783313      FALSE    ce2
## chrIV     17493791      FALSE    ce2
## chrV      20922231      FALSE    ce2
## chrX      17718849      FALSE    ce2
## chrM       13794        TRUE     ce2

gendesc <- as(Celegans, "GenomeDescription")
class(gendesc)

## [1] "GenomeDescription"
## attr(,"package")
## [1] "GenomeInfoDb"

gendesc

## | organism: Caenorhabditis elegans (Worm)
## | provider: UCSC
## | provider version: ce2
## | release date: Mar. 2004
## | release name: WormBase v. WS120
## | ---
## | seqlengths:
## |      chrI      chrII      chrIII      chrIV      chrV      chrX      chrM
## | 15080483 15279308 13783313 17493791 20922231 17718849 13794

provider(gendesc)

## [1] "UCSC"

seqinfo(gendesc)

## Seqinfo object with 7 sequences (1 circular) from ce2 genome:
## seqnames seqlengths isCircular genome
## chrI      15080483      FALSE    ce2
## chrII     15279308      FALSE    ce2
## chrIII    13783313      FALSE    ce2
## chrIV     17493791      FALSE    ce2
## chrV      20922231      FALSE    ce2
## chrX      17718849      FALSE    ce2
## chrM       13794        TRUE     ce2

bsgenomeName(gendesc)

## [1] "BSgenome.Celegans.UCSC.ce2"
```

3.2 Seqinfo class

```
## Note that all the arguments (except 'genome') must have the
## same length. 'genome' can be of length 1, whatever the lengths
## of the other arguments are.
x <- Seqinfo(seqnames=c("chr1", "chr2", "chr3", "chrM"),
```

```

        seqlengths=c(100, 200, NA, 15),
        isCircular=c(NA, FALSE, FALSE, TRUE),
        genome="toy")

length(x)

## [1] 4

seqnames(x)

## [1] "chr1" "chr2" "chr3" "chrM"

names(x)

## [1] "chr1" "chr2" "chr3" "chrM"

seqlevels(x)

## [1] "chr1" "chr2" "chr3" "chrM"

seqlengths(x)

## chr1 chr2 chr3 chrM
## 100 200 NA 15

isCircular(x)

## chr1 chr2 chr3 chrM
## NA FALSE FALSE TRUE

genome(x)

## chr1 chr2 chr3 chrM
## "toy" "toy" "toy" "toy"

x[c("chrY", "chr3", "chr1")] # subset by names

## Seqinfo object with 3 sequences from 2 genomes (NA, toy):
##   seqnames seqlengths isCircular genome
##   chrY      NA      NA    <NA>
##   chr3      NA      FALSE    toy
##   chr1     100      NA      toy

## Rename, drop, add and/or reorder the sequence levels:
xx <- x
seqlevels(xx) <- sub("chr", "ch", seqlevels(xx)) # rename
xx

## Seqinfo object with 4 sequences (1 circular) from toy genome:
##   seqnames seqlengths isCircular genome
##   ch1      100      NA      toy
##   ch2      200      FALSE    toy
##   ch3      NA      FALSE    toy
##   chM      15      TRUE     toy

seqlevels(xx) <- rev(seqlevels(xx)) # reorder
xx

## Seqinfo object with 4 sequences (1 circular) from toy genome:
##   seqnames seqlengths isCircular genome
##   chM      15      TRUE     toy

```

```
##   ch3          NA      FALSE   toy
##   ch2          200     FALSE   toy
##   ch1          100      NA     toy

seqlevels(xx) <- c("ch1", "ch2", "chY") # drop/add/reorder
xx

## Seqinfo object with 3 sequences from 2 genomes (toy, NA):
##   seqnames seqlengths isCircular genome
##   ch1       100        NA      toy
##   ch2       200      FALSE   toy
##   chY        NA        NA   <NA>

seqlevels(xx) <- c(chY="Y", ch1="1", "22") # rename/reorder/drop/add
xx

## Seqinfo object with 3 sequences from 2 genomes (NA, toy):
##   seqnames seqlengths isCircular genome
##   Y         NA        NA   <NA>
##   1         100      NA     toy
##   22        NA        NA   <NA>

y <- Seqinfo(seqnames=c("chr3", "chr4", "chrM"),
              seqlengths=c(300, NA, 15))
y

## Seqinfo object with 3 sequences from an unspecified genome:
##   seqnames seqlengths isCircular genome
##   chr3      300        NA   <NA>
##   chr4      NA        NA   <NA>
##   chrM      15        NA   <NA>

merge(x, y) # rows for chr3 and chrM are merged

## Warning in .Seqinfo.mergexy(x, y): Each of the 2 combined objects has sequence
## levels not in the other:
## - in 'x': chr1, chr2
## - in 'y': chr4
## Make sure to always combine/compare objects based on the same reference
## genome (use suppressWarnings() to suppress this warning).

## Seqinfo object with 5 sequences (1 circular) from 2 genomes (toy, NA):
##   seqnames seqlengths isCircular genome
##   chr1      100        NA      toy
##   chr2      200      FALSE   toy
##   chr3      300      FALSE   toy
##   chrM      15       TRUE    toy
##   chr4      NA        NA   <NA>

suppressWarnings(merge(x, y))

## Seqinfo object with 5 sequences (1 circular) from 2 genomes (toy, NA):
##   seqnames seqlengths isCircular genome
##   chr1      100        NA      toy
##   chr2      200      FALSE   toy
##   chr3      300      FALSE   toy
```

```
## chrM      15      TRUE    toy
## chr4      NA      NA     <NA>

## Note that, strictly speaking, merging 2 Seqinfo objects is not
## a commutative operation, i.e., in general 'z1 <- merge(x, y)'
## is not identical to 'z2 <- merge(y, x)'. However 'z1' and 'z2'
## are guaranteed to contain the same information (i.e. the same
## rows, but typically not in the same order):
suppressWarnings(merge(y, x))

## Seqinfo object with 5 sequences (1 circular) from 2 genomes (toy, NA):
## seqnames seqlengths isCircular genome
## chr3      300      FALSE    toy
## chr4      NA      NA     <NA>
## chrM      15      TRUE     toy
## chr1      100      NA      toy
## chr2      200      FALSE    toy

## This contradicts what 'x' says about circularity of chr3 and chrM:
isCircular(y)[c("chr3", "chrM")] <- c(TRUE, FALSE)
y

## Seqinfo object with 3 sequences (1 circular) from an unspecified genome:
## seqnames seqlengths isCircular genome
## chr3      300      TRUE     <NA>
## chr4      NA      NA     <NA>
## chrM      15      FALSE    <NA>

if (interactive()) {
  merge(x, y) # raises an error
}
```

4 Examples

4.1 converting seqlevel styles (eg:UCSC to NCBI)

A quick example using *Drosophila Melanogaster*. The txdb object contains seqlevels in UCSC style, we want to convert them to NCBI

```
txdb <- TxDb.Dmelanogaster.UCSC.dm3.ensGene
seqlevels(txdb)

## [1] "chr2L"      "chr2R"      "chr3L"      "chr3R"      "chr4"      "chrX"
## [7] "chrU"       "chrM"       "chr2LHet"   "chr2RHet"   "chr3LHet"   "chr3RHet"
## [13] "chrXHet"    "chrYHet"    "chrUextra"

genomeStyles("Drosophila melanogaster")

##   circular sex auto NCBI    UCSC           Ensembl
## 1   FALSE FALSE TRUE  2L    chr2L           2L
## 2   FALSE FALSE TRUE  2R    chr2R           2R
## 3   FALSE FALSE TRUE  3L    chr3L           3L
```

```
## 4      FALSE FALSE  TRUE   3R      chr3R                      3R
## 5      FALSE FALSE  TRUE    4      chr4                      4
## 6      FALSE  TRUE FALSE   X      chrX                      X
## 7      FALSE  TRUE FALSE   Y      chrY                      Y
## 8          TRUE FALSE FALSE  MT      chrM dmel_mitochondrion_genome
## 9      FALSE FALSE FALSE 2LHet  chr2LHet                  2LHet
## 10     FALSE FALSE FALSE 2Rhet  chr2RHet                  2RHet
## 11     FALSE FALSE FALSE 3LHet  chr3LHet                  3LHet
## 12     FALSE FALSE FALSE 3Rhet  chr3RHet                  3RHet
## 13     FALSE FALSE FALSE Xhet   chrXHet                  XHet
## 14     FALSE FALSE FALSE Yhet   chrYHet                  YHet
## 15     FALSE FALSE FALSE  Un     chrU                      U
## 16     FALSE FALSE FALSE <NA> chrUextra                  Uextra
```

```
mapSeqlevels(seqlevels(txdb), "NCBI")
```

```
##      chr2L      chr2R      chr3L      chr3R      chr4      chrX      chrU
##      "2L"      "2R"      "3L"      "3R"      "4"      "X"      "Un"
##      chrM chr2LHet chr2RHet chr3LHet chr3RHet chrXHet chrYHet
##      "MT"  "2LHet"  "2Rhet"  "3LHet"  "3Rhet"  "Xhet"  "Yhet"
## chrUextra
##      NA
```

4.2 converting styles and removing unwanted seqlevels

Suppose we read in a Bam file or a BED file and the resulting GRanges have a lot of seqlevels which are not required by your analysis or you want to rename the seqlevels from the current style to your own style (eg:USCS to NCBI), we can use the functionality provided by GenomeInfoDb to do that.

Let us say that we have extracted the seqlevels of the Seqinfo object(say GRanges from a BED file) in a variable called "sequence".

```
sequence <- seqlevels(x)

## sequence is in UCSC format and we want NCBI style
newStyle <- mapSeqlevels(sequence,"NCBI")
newStyle <- newStyle[complete.cases(newStyle)] # removing NA cases.

## rename the seqlevels
x <- renameSeqlevels(x,newStyle)

## keep only the seqlevels you want (say autosomes)
auto <- extractSeqlevelsByGroup(species="Homo sapiens", style="NCBI",
                               group="auto")
x <- keepSeqlevels(x,auto)
```

5 Session Information

Here is the output of `sessionInfo` on the system on which this document was compiled:

```
toLatex(sessionInfo())
```

- R Under development (unstable) (2019-12-14 r77572), x86_64-apple-darwin15.6.0
- Locale: C/en_US.UTF-8/en_US.UTF-8/C/en_US.UTF-8/en_US.UTF-8
- Running under: OS X El Capitan 10.11.6
- Matrix products: default
- BLAS:
/Library/Frameworks/R.framework/Versions/4.0/Resources/lib/libRblas.0.dylib
- LAPACK:
/Library/Frameworks/R.framework/Versions/4.0/Resources/lib/libRlapack.dylib
- Base packages: base, datasets, grDevices, graphics, methods, parallel, stats, stats4, utils
- Other packages: AnnotationDbi 1.49.0, BSgenome 1.55.2, BSgenome.Celegans.UCSC.ce2 1.4.0, Biobase 2.47.2, BiocGenerics 0.33.0, Biostrings 2.55.4, GenomeInfoDb 1.23.6, GenomicFeatures 1.39.2, GenomicRanges 1.39.1, IRanges 2.21.3, S4Vectors 0.25.10, TxDb.Dmelanogaster.UCSC.dm3.ensGene 3.2.2, XVector 0.27.0, rtracklayer 1.47.0
- Loaded via a namespace (and not attached): BiocFileCache 1.11.4, BiocManager 1.30.10, BiocParallel 1.21.2, BiocStyle 2.15.5, DBI 1.1.0, DelayedArray 0.13.2, GenomeInfoDbData 1.2.2, GenomicAlignments 1.23.1, Matrix 1.2-18, R6 2.4.1, RCurl 1.95-4.12, RSQLite 2.2.0, Rcpp 1.0.3, Rsamtools 2.3.2, SummarizedExperiment 1.17.1, XML 3.98-1.20, askpass 1.1, assertthat 0.2.1, backports 1.1.5, biomaRt 2.43.1, bit 1.1-15.1, bit64 0.9-7, bitops 1.0-6, blob 1.2.0, compiler 4.0.0, crayon 1.3.4, curl 4.3, dbplyr 1.4.2, digest 0.6.23, dplyr 0.8.3, evaluate 0.14, glue 1.3.1, grid 4.0.0, highr 0.8, hms 0.5.3, htmltools 0.4.0, httr 1.4.1, knitr 1.26, lattice 0.20-38, magrittr 1.5, matrixStats 0.55.0, memoise 1.1.0, openssl 1.4.1, pillar 1.4.3, pkgconfig 2.0.3, prettyunits 1.1.0, progress 1.2.2, purrr 0.3.3, rappdirs 0.3.1, rlang 0.4.2, rmarkdown 2.0, stringi 1.4.5, stringr 1.4.0, tibble 2.1.3, tidyselect 0.2.5, tools 4.0.0, vctrs 0.2.1, xfun 0.12, yaml 2.2.0, zeallot 0.1.0, zlibbioc 1.33.0